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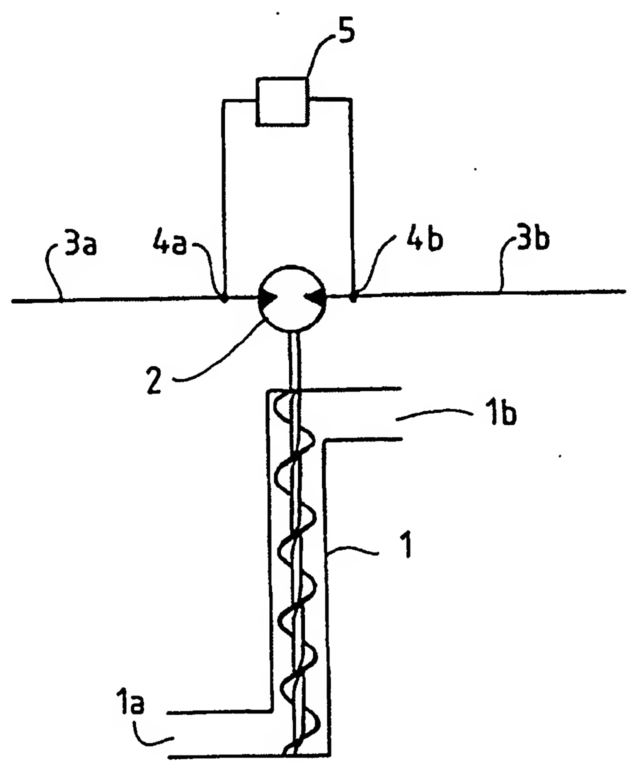
(57) Abstract

An apparatus for metering flow of solid particulate matter comprising: a transportation means (1) driven at known speed by motor (2) a measuring means (4a, 4b, 5) for measuring the torque or force required to drive said transportation means wherein said measuring means can be used to calibrate said torque or force against the mass flow of said solid particulate matter as said matter is moved by said transportation means.



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MASS FLOW METERING

The present invention relates to a method and apparatus for metering mass flow of particulate or finely divided matter.

It is often necessary to feed particulate solid matter to a delivery point at an accurately known rate or in an accurately known quantity. Commonly such solid matter is bulk stored in a large container and is transported by a main auger or the like which feeds the solid matter out of the container. A smaller transportation means such as an inclined auger may then be used to deliver specific small quantities to a delivery point.

In many applications it is very important that the rate or quantity of solid matter delivered is known accurately. For example, bulk explosive compositions are often produced by mixing together raw materials on a modified truck called a mobile manufacturing unit (MMU). Typically, solid particulate oxidiser salts such as prilled ammonium nitrate (PAN) are augered from a storage bin on the truck into an emulsion/fuel oil mix to make various products of differing oxidiser salt content. To achieve the desired product composition, accurate metering of each raw material is essential, particularly the amount of solid particulate matter delivered by the auger.

In the past it has been common practice to calibrate the rate of feed of solid matter by an auger and then use the calibration to meter the volumetric displacement of the solid matter per revolution of the auger. With this method of measurement it is assumed that for every revolution of the auger, a certain volume of solid matter is shifted. However it is often difficult to measure volumetric displacement accurately. It is

particularly difficult to make such measurements where the solid matter is of variable density or has a tendency to cake or hang-up in the storage container.

Prilled ammonium nitrate is one example of a solid material which is particularly prone to caking and hang-ups. Furthermore the prill density can vary from one production batch to another and from one supplier to another. It has also been observed that MMU's having separate compartments for storage of PAN often suffer variable PAN delivery rates as each bin empties.

Currently the emulsion and fuel oil components of an explosive composition produced on an MMU are metered accurately by positive displacement pumps with constant operating back pressures. Metering of PAN is achieved using calibrated mass delivery based on the volumetric displacement of a belly auger but the accuracy of this material feed is extremely variable due to the aforementioned physical properties of PAN. PAN metering must be accurate over periods of time as short as 10 seconds, through to period of several hours. The metering must remain accurate in the varying operating conditions of an MMU on a mine bench where the terrain is often rugged and necessitates the use of augers at varying inclinations and at extremes of air temperature. The volumetric displacement measurement methods of the prior art have proved to be of variable efficiency when the auger is steeply inclined. If PAN is not accurately metered then the bulk explosive products into which the PAN is incorporated may be outside specification or of inferior quality.

It has now been found that an improved method of monitoring flow of solid particulate matter may be provided by measuring the energy requirements of the inclined auger. This reflects the rate of delivery more accurately than the

aforementioned measurement methods where a certain mass is assumed to be delivered by each revolution of the auger. The current invention therefore provides a method of metering flow of solid particulate matter comprising the steps of:

(a) moving portions of said solid particulate matter along a transportation means driven at known speed by a motor;

(b) measuring the force required to drive the transportation means; and

(c) calibrating said force to the mass flow of said material.

The transportation means of the current invention may be any contrivance which can be situated at a fixed location while facilitating movement of matter from a loading point to a delivery point. This includes augers, tubeveyors, conveyor belts and the like which have moving parts but do not generally change location while in use.

If the transportation means is run at a constant speed the volumetric displacement can be considered constant therefore any change in power of the motor is proportional to pressure drop across the motor. In other words, when the transportation means runs at constant speed the power required to transfer the solid particulate matter is a function of the load moved and therefore, the force of the motor expressed as torque.

In a preferred embodiment of the current invention the torque required to drive the transportation means is measured by monitoring the differential pressure between the hydraulic lines to the motor which drives the transportation means. The pressure drop across the

hydraulic motor may be measured, for example, by a differential pressure transducer connected to the inlet and outlet lines of the hydraulic motor and many other devices suitable for measuring pressure drop across the hydraulic motor will be apparent to those skilled in the art. As the amount of work done by the hydraulic motor changes with the amount of solid particulate matter being moved by the transportation means, the pressure in the hydraulic lines will change accordingly for a given constant speed of the transportation means. Thus measurement of the differential pressure between the hydraulic lines will give a measure of mass flow.

In a particularly preferred embodiment the transportation means is an auger, tubeveyor or the like. In situations where a main auger shifts solid material out of a storage container and a shorter auger moves the material to a delivery point it will be apparent to those skilled in the art that it is most practical to measure the torque of the smaller auger motor. In practice the main auger can be adjusted to a chosen rate of revolutions per minute to obtain a nominal delivery of solid material required. Output from a tachometer may be used to verify that the nominal delivery rate has been achieved.

In situations where the transportation means comprises a drive shaft it may be desirable to directly measure the torque on the drive shaft using transducers located in a drive means. Magnetic sensors located at either end of the drive shaft can be used to measure the twist of the shaft as a function of displacement between the two sensors. Where an electric motor drive is used, the electrical power to the motor can be measured in preference to measuring the torque on the drive shaft. One of the advantages of the method of mass flow metering of the current invention is that the system can be calibrated to compensate for fore, aft and/or sideways tilt or incline

of the mass transportation means.

The present invention will now be described with reference to Figure 1 and Figure 2 which depict inclined augers for transporting solid particulate matter. Figure 3 is referred to in the Example and is a graph of the results of calibrating actual mass flow of PAN being transferred by the auger of an MMY against the pressure drop across the auger motor.

Figure 1 depicts a plan view of an inclined auger (1) for transporting solid particulate matter. The solid particulate matter enters the auger through the lower port (1a) and leaves the auger through the upper port (1b). A hydraulic motor (2) drives the inclined auger and is connected to two hydraulic lines (3a,3b). Hydraulic fluid from a pump passes to the hydraulic motor through one hydraulic line (3a) and from the hydraulic motor to a tank through the other hydraulic line (3b). Pressure transducers (4a,4b) are located in the hydraulic lines on either side of the hydraulic motor. Both pressure transducers are connected to a differential pressure gauge (5) which measures the difference in hydraulic pressure recorded by the pressure transducers. The difference in pressures can be equated to torque of the hydraulic motor and therefore the force required to move solid particulate matter along the auger.

In Figure 2 also depicts an inclined auger (1) driven by a hydraulic motor (2) and a single pressure transducer (4) is connected to both hydraulic lines (3a,3b). A meter (5) displays the pressure drop in any convenient units.

The invention is further described with reference to the following non-limiting example.

EXAMPLES

Example 1

An MMU for mixing bulk emulsion explosives was fitted with pressure transducers to measure the pressure drop across an existing 10" incline auger hydraulic motor. The auger was used for moving PAN and the pressure transducers used were rated at 200 bar. The pressure drop across the motor was calibrated to the actual mass being transferred by the auger and the results are recorded in Figure 3. The X-axis of the graph relates to the mass flow (in kilograms per minute) of PAN delivered by the auger while the Y-axis relates to the pressure drop across the transducers measured electrically by a differentiometer (in millivolts).

The graph depicted in Figure 3 shows that there is a linear relationship between the energy required and the amount of solid matter delivered. Metering mass flow using this method has been proven up to a stage that it can be used as the primary indicator of PAN flow for production of bulk explosives formulations comprising PAN on MMUs.

Example 2(a)

The system of mass flow metering described in Example 1 was monitored for accuracy in monitoring PAN flow over a one month period during which time the system was recalibrated weekly. The system was run for varying periods of time from 10 seconds to 3 hours with PAN flow rates of up to 704 kg/min. Results are recorded in Table 1.

Example 2(b)

The system of mass flow metering used for monitoring PAN flow in Example 2(a) was monitored for accuracy over a further one month period during which time no calibrations were carried out. As per Example 2(a) the system was run for varying periods of time from 10 seconds

to 3 hours and with PAN flow rates of up to 704 kg/min. Results are recorded in Table 1.

Comparative Example 2(a)

To provide a comparison of accuracy of the mass flow metering method of the current invention with methods of the prior art, a system of mass flow metering using volumetric displacement measurement was put into service on an MMU. The system was used for monitoring PAN flow over a one month period during which time the mass flow metering system was recalibrated weekly. The system was run for varying periods of time from 10 seconds to 3 hours with PAN flow rates of up to 704 kg/min. Results are recorded in Table 1.

Comparative Example 2(b)

The system of volumetric displacement mass flow metering of Comparative Example 2(a) was monitored for accuracy over a further one month period during which time no further calibrations were carried out. As per Comparative Example 2(a) the system was run for varying periods of time from 10 seconds to 3 hours and with PAN flow rates of up to 704 kg/min. Results are recorded in Table 1.

All accuracy values in Table 1 are quoted at a 95% confidence interval (two standard deviations). The accuracy values recorded show a significant improvement in accuracy of AN prill flow measurement where the method of the current invention has been used (Examples 2(a) and 2(b)) as compared with the method of the prior art (Comparative Examples 2(a) and 2(b)). It will be apparent that accuracy of the method of the current invention may be further improved by fitting a tachometer and inclinometer to the transportation means and using the output from these devices to modify the mass flow meter output. Accuracy may be further improved by regularly recalibrating the mass

flow system by checking the zero position of the mass flow meter output.

Table 1

	Example 2(a)	Comparative Example 2(a)	Example 2(b)	Comparative Example 2(b)
Accuracy (kg/min)	± 44	± 8.4	± 52	± 22

Example 3

The system of mass flow metering of Example 1 was used at five different target flow rates at various auger speeds. Figure 4 shows a plot of the flow rate as recorded by the mass flow meter of the system versus the auger speed as measured in rpm. The auger was transporting AN prill.

Figure 4 shows that even over a wide mass flow range, the relationship between the mass flow meter reading and incline auger speed remains constant at given flow rates.

Example 4

An MMU for mixing bulk emulsion explosives was fitted with two magnetic sensors, one at either end of the drive shaft of a 10" incline auger. The auger was used for moving PAN from a storage bin to a mixing device where the PAN is mixed into a water-in-oil emulsion composition.

The PAN was delivered into the mixing device at rates of between 15 and 550 kg/min for up to 5 hours at a time. The amount of twist was measured on the shaft as a function of the displacement between signals of the two magnetic sensors. Because the torque changes with the amount of torque performed by the auger the displacement between the signals provides a measure of mass flow.

The use of magnetic sensors to measure PAN mass

flow was monitored over a period of one month during which time the system of mass flow metering was recalibrated weekly. At the end of this period the accuracy of the system was calculated as ± 3.2 kg/min. It is believed that this method of mass flow measurement using magnetic sensors located in an auger shaft may be more accurate than measurement using hydraulic pressure drop across an auger hydraulic motor because use of the magnetic sensors removes any hydraulic motor effects such as those which may be caused by varying hydraulic oil temperature or viscosity.

While the invention has been explained in relation to its preferred embodiments it is to be understood that various modifications thereof will become apparent to those skilled in the art upon reading the specification. Therefore, it is to be understood that the invention disclosed herein is intended to cover such modifications as fall within the scope of the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An apparatus for metering flow of solid particulate matter comprising:

a transportation means driven at known speed by a motor,

a measuring means for measuring the torque or force required to drive said transportation means

wherein said measuring means can be used to calibrate said torque or force against the mass flow of said solid particulate matter as said matter is moved by said transportation means.

2. An apparatus for metering flow of solid particulate matter according to claim 1 wherein said motor is hydraulically driven and said measuring means measures the differential pressure between the hydraulic lines of said hydraulic motor.

3. An apparatus for metering flow of solid particulate matter according to claim 1 wherein the transportation means comprises a drive shaft and said measuring means measures the torque on said drive shaft.

4. An apparatus for metering flow of solid particulate matter according to claim 1 wherein the transportation means comprises a drive shaft and said motor is an electric motor and said measuring means measures the electrical power to said electric motor.

5. An apparatus for metering flow of solid particulate matter according to any of claims 1 to 4 wherein said solid particulate matter comprises at least one oxidiser salt.

6. An apparatus for metering flow of solid particulate matter according to any of claims 1 to 5 wherein said solid particulate matter comprises prilled

ammonium nitrate.

7. An apparatus according to any of claims 1 to 6 wherein said apparatus is used in the production of explosives formulations.

8. An apparatus according to any of claims 1 to 7 wherein said apparatus is used in the production of bulk explosive formulations on mobile manufacturing units.

9. A method of metering flow of solid particulate matter comprising the steps of:

(a) moving portions of said solid particulate matter along a transportation means driven at known speed by a motor,

(b) measuring the torque or force required to drive the transportation means; and

(c) calibrating said torque or force to the mass flow of said material.

10. A method of metering flow of solid particulate matter according to claim 9 wherein the force required to drive the transportation means is measured by monitoring differential pressure between the hydraulic lines to the hydraulic motor.

11. A method of metering flow of solid particulate matter according to claim 9 wherein the transportation means comprises a drive shaft and the force required to drive the transportation means is measured by monitoring the torque on the drive shaft.

12. A method of metering flow of solid particulate matter according to claim 9 wherein the transportation

means comprises a drive shaft driven by an electric motor and the force required to drive the transportation means is measured by monitoring the electrical power to the electric motor.

13. A method of metering flow of solid particulate matter according to any of claims 9 to 12 wherein the solid particulate matter comprises an oxidiser salt.

14. A method of metering flow of solid particulate matter according to any of claims 9 to 14 wherein said method is used for the production of explosives formulations.

15. A method of metering flow of solid particulate matter according to any of claims 9 to 13 wherein said solid particulate matter comprises prilled ammonium nitrate and method is used for the production of bulk explosives formulations comprising prilled ammonium nitrate on mobile manufacturing units.

16. A method for metering flow of solid particulate matter substantially as herein described with reference to the Figures and Examples.

17. An apparatus for metering flow of solid particulate matter substantially as herein described with reference to the Figures and Examples.

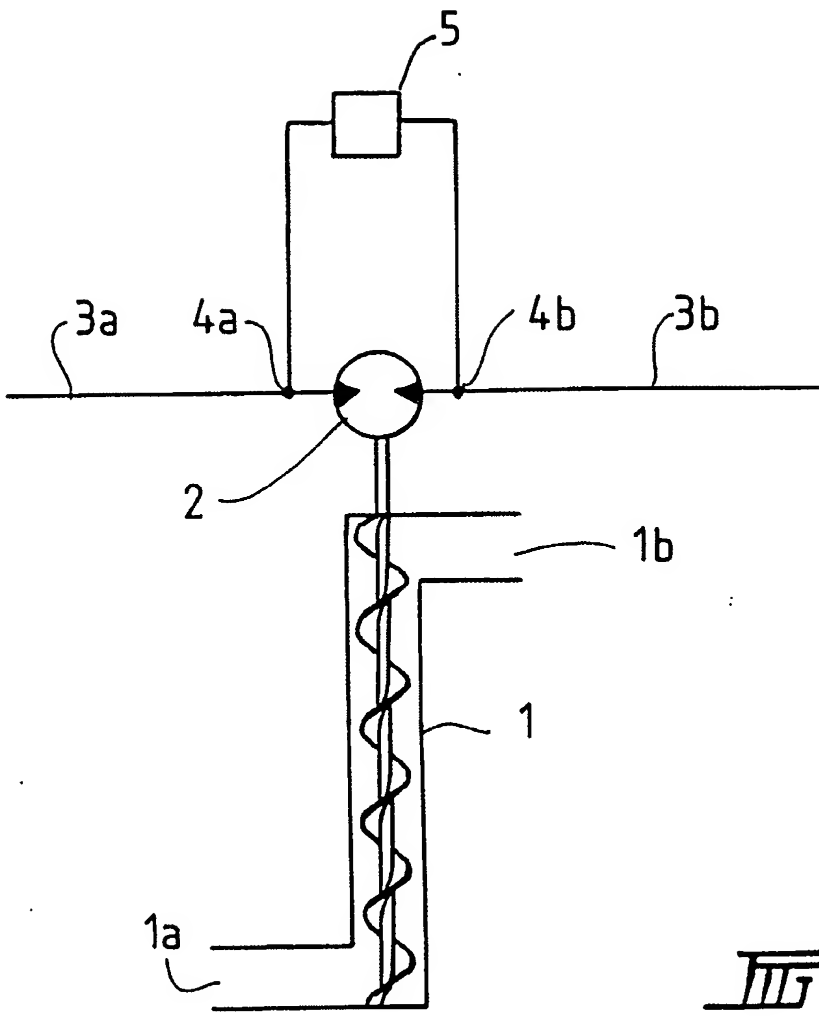

FIG. 1.

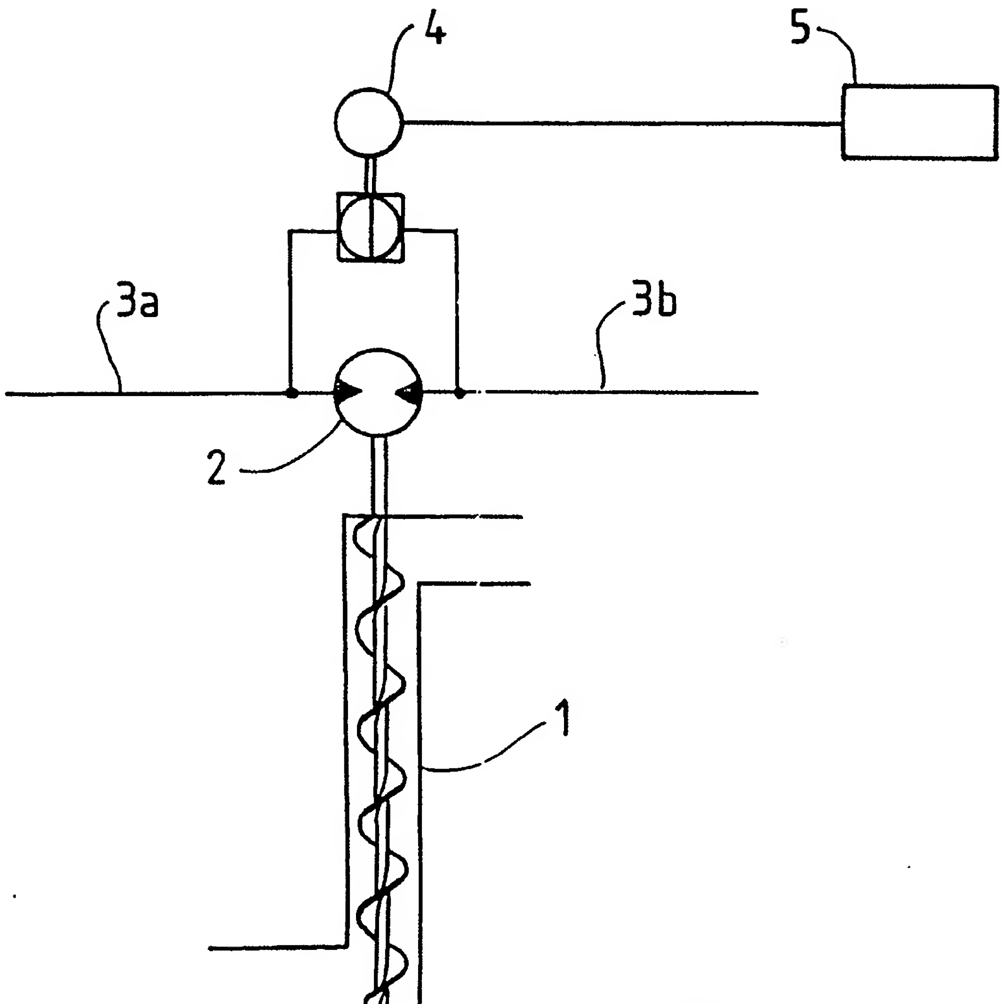

FIG. 2.

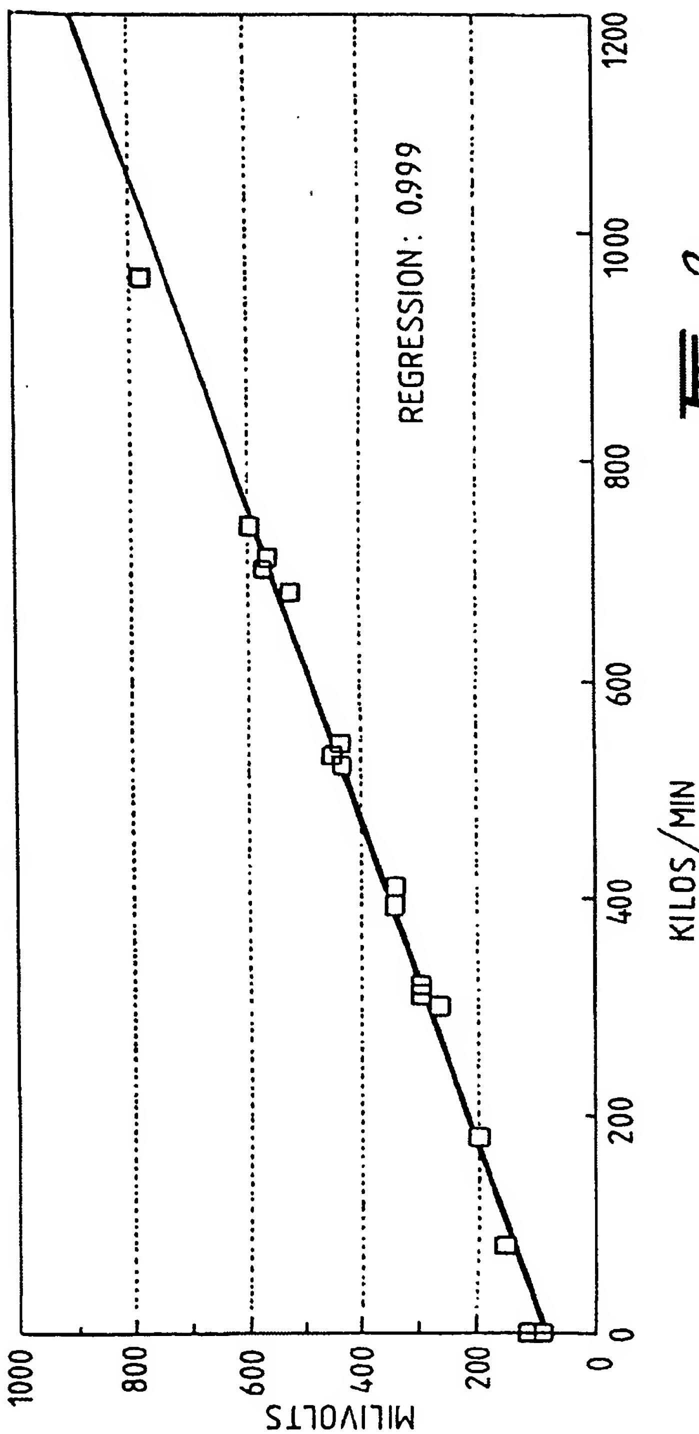
MILIVOLTS
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
REGRESSION: 0.999
KILOS/MIN

FIG. 3.

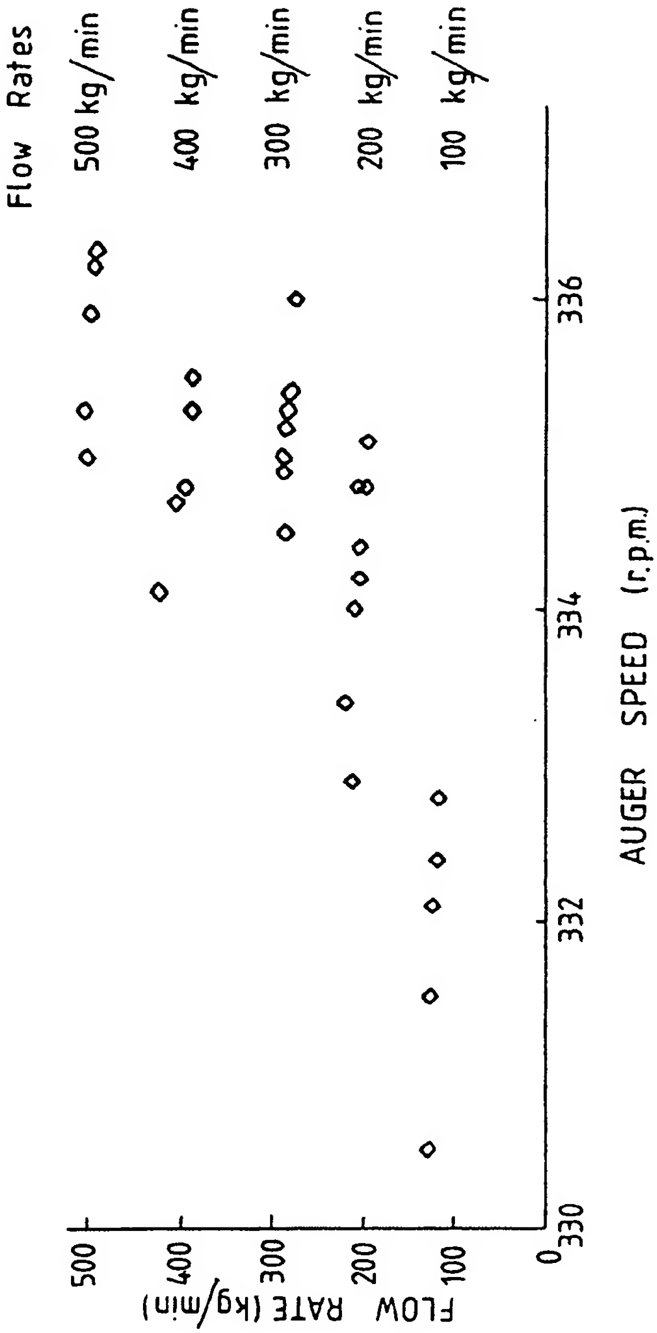
Target Flow Rates
500 kg/min
400 kg/min
300 kg/min
200 kg/min
100 kg/min
FLOW RATE (kg/min)
AUGER SPEED (r.p.m.)
330
332
334
336
0
100
200
300
400
500

FIG. 4.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00256

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.^{6} G01F 1/86, 1/88, 1/90, 9/00, 13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: G01F 1/34, 1/56, 1/86, 1/88, 1/90, 9/00, 13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US,A, 3834474 (Knol) 10 September 1974 See Abstract and column 1, line 50 to column 2, line 41	1-6, 9-13
X	FR,A, 2672677 (F CB S.A.) 14 August 1992 See Abstract	1-6, 9-13
P,Y	US,A, 5318409 (London et al) 7 June 1994 See Column 3, lines 34 to 64	1-6, 9-13
Y	AU,B, 18598/83 (567113) (Hannaford, Alfa G. Pty. Ltd) See page 4 lines 1 to 19	1-6, 9-13

☐ Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
14 June 1995	21 JUNE 1995 (21.06.95)
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	Authorized officer S. Clark Telephone No. (06) 2832164

C(Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
A	Patents Abstract of Japan, P-1137, page 135, JP,A, 2-231530 (Yamato Scale Co. Ltd) 13 September 1990, See Abstract	1-9
A	Derwent Abstract Accession No. 94-046868/06, Class S02, RU,A,2000548 (Amelkin A K) 7 September 1993, See Abstract	1-9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00256

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Patent Document Cited in Search Report	Patent Family Member		
US 3834474	BE 774018 ES 396086 NL 7015227	CH 544295 FR 2111669 YU 2642/71	DE 2151441 GB 1370358
US 5318409	CA 2119906		
AU 18598/83	CA 1211637	US 4798280	ZA 8306445
			END OF ANNEX